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The global, in some part rapidly proceeding, anthropogeneous processes require a comprehensive service for bringing out both the global and regional environmental changes and strong local shifts in the nature equilibrium. As seen from the first analysis, the space methods must be one of the main environmental conservation services. In his message to the COSPAR session in Leningrad in May 1970, the U.N. Secretary U'Tan stated that "the promises presented in this field (space applications technology) are so vast that for the first time man may very well have the ability to understand his environment and conserve as well as exploit it."

Space methods of environmental studies are defined as a complex of apparatus and methodological elaborations for investigation of the composition, structure, dynamics, and rhythmics of the geosphere through the interpretation of image and spectra of the earth's electromagnetic field as obtained from space vehicles (Vinogradov, Kondratyev, 1971).

In studying the anthropogeneous features, one should determine the principal advantages of space methods for studies of the man-made environment:

1. detection and identification of anthropogeneous features for evaluating the depth of environmental transformation;

2. tracking of extension and mapping of anthropogeneous features for determining the degree and dimensions of man-made effects;

3. revealing the continuity and frequency of anthropogeneous features for determining the degree and rate of nature transformation;

4. quantitative evaluation of anthropogeneous effects;

5. analysis of equilibrium of cultural and natural conjugated factors and prediction of their changes.

At present, the problem with the space approach to studying the man-made environment is confined to the first point, viz., to their detection.

In regard to the forms of anthropogeneous effects and the indicators used, three groups are distinguished. The first one, occurring simultaneously with survey, is distinguished as the direct indicators. Such is the imagery of fires, smoke plumes, oil slicks, arable lands, and industrial works.

The second group of anthropogeneous features, formed during the last decades and centuries, is mainly recognized as the indirect indicators. They are the imageries of traces of water and wind erosion resulting from the destruction in soil and vegetation cover.

The third group involves the remote anthropogeneous landscapes formed during the last centuries and milleniums and is recognized chiefly as the logical indicators. These are savannahs formed in light tropical forests.

Space methods may be applied to detection of various anthropogeneous environmental effects: (1) industrial and urban landscapes; (2) agricultural lands, arable soils, abandoned fields; (3) forest lands, logging and recovery areas; (4) irrigated and non-irrigated lands, water supply constructions; (5) anthropogeneous water erosion; (6) anthropogeneous wind erosion; (7) forest and steppe fires and burns; (8) water pollution; (9) air pollution; and (10) changes in the radiation balance and atmospheric physics.

I. Water Pollution

A study of water pollution using space methods is presently in the stage of aircraft and theoretical modeling. The water pollution in the inland and oceanic waters is detected by different remote indicators: (1) tone and color changes influenced by transportation of suspended, washed out, and sewage materials; (2) thermal anomalies due to admixture of the exhaust waters; (3) foam formed in mixing the warm chemical and cold natural waters; (4) changes in water vegetation under influence of thermal and chemical properties; (5) rising of exhaust matter to water surface; (6) affect of active films on surface waves and scattering functions of sea surface; and (7) affect of oil and other active films on the color and spectral reflectivity of sea surface.

The aerial spectrometry and photography surveys showed the following: Spectral contrasts of pollutants in different spectral regions are different. For example, the biological pollution and foam are revealed by the changes of tone densities in different narrow-zone images; in blue (λ = 0.35 mcm) the brightness of polluted waters increases, decreasing in green (λ = 0.58 mcm), and increases again in infra-red (λ = 0.83 mcm). Other pollutants such as tannery and cannery wastes cause an extensive increase in brightness over the range of λ = 0.5 - 0.9 mcm. The infra-red photography on spectrozonal films at λ = 0.5 - 0.9 mcm must find an application for space surveys (Schurz, 1968, Lopic, Pressman, Ludlum, 1968).

Perspective for recording thermal anomalies are the infra-red spectrometric measurements in the second transmission window λ = 8 - 14 mcm. The presence of foam is shown by measurements recorded by the microwave radiation sensors.

Different active films are distinguished from space pictures, some of them being related to the sea pollution with oil waste, so-called slicks. They strongly affect the indices of light reflectance from the sea surface and, therefore, differ from clean sea surface by the brightness of specular reflectance. Within the sunglint patch, they are recognized from dark strips and spots against the light background of the clean water surface. In the lower part of the sunglint patch region, sometimes against the dark background of the clean surface water the active films (slicks) are represented by the lighter strips. This difference is explained by the fact that the indications of light reflection from the polluted sea surfaces are more symmetrical and smooth as compared with the more rough sea surface of clean water (Bowley, Greaves, Spiegel, 1969). In multizonal photography, the oil slicks are lighter than the clean water in ultraviolet region at λ = 0.32 - 0.38 mcm and darker in infra-red region at λ = 8 - 14 mcm (Low, Hassel,). The oil slick is more successfully revealed in the recording in microwave spectral region at $\lambda = 0.8 - 2.2$ cm (Ergetron, Trexler, 1970).

II. Air Pollution

At present, atmospheric pollution inspection becomes more of a problem and must be realized in the global scale since the international character of the anthropogeneous effect of this problem is the most pronounced.

One of the sources of air pollution seen from space is the industrial smoke. The second is the smoke of forest and grass fires. The latter produces a large amount of solid particles into the atmosphere, its chemical composition being slightly poisonous. The aircraft jet trails are also revealed sometimes. In this paper, we are concerned with air pollution with solid particles due to eolian wind erosion. Among the indirect indicators of air pollution is a mass affection of conifers by the industrial gases, which is reflected on infra-red photoemulsion (Wert,).

The waste source of air pollution is the dust-sand wind erosion of arable lands in desert and steppe regions. The wind erosion is determined from the local photographs--eolian relief forms and TV regional images--from zones of dust-sand flows and storms. These were determined from the TV images of ESSA satellites, the global pictures from space probe ZOND, and the photographs from manned spacecraft Gemini and SOYUZ. Photographed in the latter were dust storms in the Middle Asia, Sudan, Lybia (Wobber, 1971). However, on account of small areas (smaller 10^5 km^2) covered by one local photograph, they did not provide the structure of the dust-sand vortices and flows as a whole. The most comprehensive presentation of the dust-sand flow patterns is received from TV regional images and global photographs (Gigoryev, Lipativ, Vinogradov, 1971). (Figure 2)

Belonging to the regions of constant and well noticeable wind erosion are the desert savannahs attached from the north to the bend of the Niger valley, from the north to the Chad Lake, from the northwest to the upper Nile valley, where the savannah desertification is intensive and the critical destruction zones are situated. They are recognized from the whitish, even dull spots with diffuse boundaries masking the image of the earth surface features. Of the most interest are the regional dust-sand flows associated with wind erosion on the Soudan and Near East (Vinogradov, Grigoryev, Lipatov paper presented at the XXII I.A.F. Congress).

The first astronauts noted that from space one could see the smoke plumes not only from large works but also from the smaller sources of smoking--sea vessels (Cooper, , Nikolayev, Popovitch,). However, the most convincing results were obtained from the analysis of the pictures from manned spacecraft Gemini and SOYUZ (Ronderson, 1968, Wobber, 1969). We revealed from photographic densities three groups of solid concentration in the atmosphere. The high particle concentration is well confined, giving a noticeable shadow on the earth surface and entirely masking the surface features. The middle particle concentration is revealed as the light cloud plumes. The middle particle concentration is also noticeable from light gray tone but yields diffuse boundaries, and the most contrasting surface features are seen through the middle cover of smoke plume. The moderate concentration of solid particles is revealed as a transparent fog, and many surface features are seen through it. Photographic receivers are restricted to a large number of solid particles in the atmosphere. The concentration of about 10^5 part/m^3 seems to be the limit of tracking smoke plumes. The shape of the smoke plume image in a space picture is dependent on meteorological conditions. As a rule, smoke plumes are well expressed under conditions of the stable atmosphere with the wind velocity of 2-4 point, particularly with the presence of atmospheric inversion with the slight turbulent violation; i.e., under such meteorological situation when the air smoking must give the most negative effect. The plume dimensions observed reach tens of kilometers and can transect the state boundaries (figure 3).

Photographic sensors give a detailed spatial picture of the smoke plume distribution but provide less information on composition of pollutants. Because of this, for space remote sensing of air pollution, the spectrophotometric methods should be used (Barringer, Newbury, Moffat, 1968, Kondratyev, 1970).

The air pollution inspection in the ultraviolet spectral region is based on the recording by aerospace sensors of solar energy reflected from the earth's surface. In the correlation spectrometer, the reflected radiation is assembled by telescope and dispersed by prism. The spectrum is projected on the optical mask bearing the photographic replica of the atmospheric admixture to be detected. The identification is made by the analogy of the signal and reflectance variations. The degree of similarity indicates the absolute content of the atmospheric admixture. In the case of SO_2 absorption band at $\lambda = 0.3$ mcm, the measurement is conducted on the wings of ozone band where the absorption is too small to prevent the measurements of SO_2 absorption. To isolate the surface reflection from the light scattering by ozone, it is necessary to measure the back scattering at λ 0.29 mcm, where the whole light is due to its ozone content, and to calculate the back scattering of SO_2 within the range of $\lambda = 0.31$ mcm. The possibilities of measuring NO_2 are much fewer since in the NO_2 band, about $\lambda = 0.43$ mcm, there is more light reflected from the earth's surface.

Mapping the air pollution in the Toronto region was undertaken from an altitude of about 3 km. The weak pollution was, naturally, recorded from windward; and the strong, from the lee of the town. The main sources of pollutants SO_2 and NO_2--thermal power station and oil refineries--were discovered. The relative concentrations were found to be 0 - 150 ppm/meter (Barringer, Newburry, Moffet, 1968). On the basis of this satellite system for permanent tracking, the atmospheric pollution experiment is being planned (Barringer, Schock, 1966). Such system is supposed to be installed on Nimbus satellites for transversal scanning of the band 580 km wide with resolution of about 20 km. This permits one to determine: (1) flows of polluted air masses of industrial areas; (2) regional air pollution, the distribution and the polluting structure; and (3) foundation of concept of the global pollution.

Fires are a serious source of air pollution. When observed from space, they do not seem to be accidental phenomena.

In the local photography, one can see that in savannah during the dry pre-rain period fires occur at an average of 500 - 1,000 km^2. The visible fire plumes alone spread over an area up to 50 - 60 km. A smaller number of fires is observed in the forest zone. Here, judging from the TV picture of Alaska, one visible forest fire in summer 1969 burned 40,000 km^2. Smoke trains of forest fires as seen from TV images amount to 1,200 - 400 km (Singer, 1962, Ronderson, 1968, Parmenter, 1969). The vegetation fires, being considerably larger than the plumes, send to the atmosphere a large number of solid particles.

Pollution caused by jet aircraft streams is seen in space photographs when the pollutants are the fog-producing concentration nuclei; it is the fog that is distinguished in the photographs and TV images (Fay, Heywood, Linden, 1969, George, Varssen, Chass, 1969). The typical pollutants NO, SO, and CO behind the aircraft are very persistent; the shift of particles increases their atmospheric buoyancy. When the jet streams are above the clouds, they are recognized by a thin-cast, darkish gray shadow. The resolution of these streams increases due to the linearity of the object, their extension reaching tens of kilometers.

Summary

Space sensors derive information about almost all forms of anthropogeneous modification of environment. Space detectors show global dimensions of this effect. This, in turn, requires the development of a wide international program of observation. It is clear that a global protection service can be realized only on the basis of space methods whose application is beyond the state and regional boundaries. In this connection, there arises a necessity for international cooperation in the field of space surveillance and the detection of the negative forms of man's influence on the environment. Thus, the protection service must become one of the most important (perhaps the most important) parts of the forthcoming program of Earth Resources Satellites or Manned Orbital Stations (Miller, Gurk, 1968, Vinogradov, Kondratyev, 1970).

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FIGURE 1. Active organic films over the sea surface, South China Sea, are recognized by the dark twisted strips in the upper part of sunglint area or by the light strips in the lower part of it.

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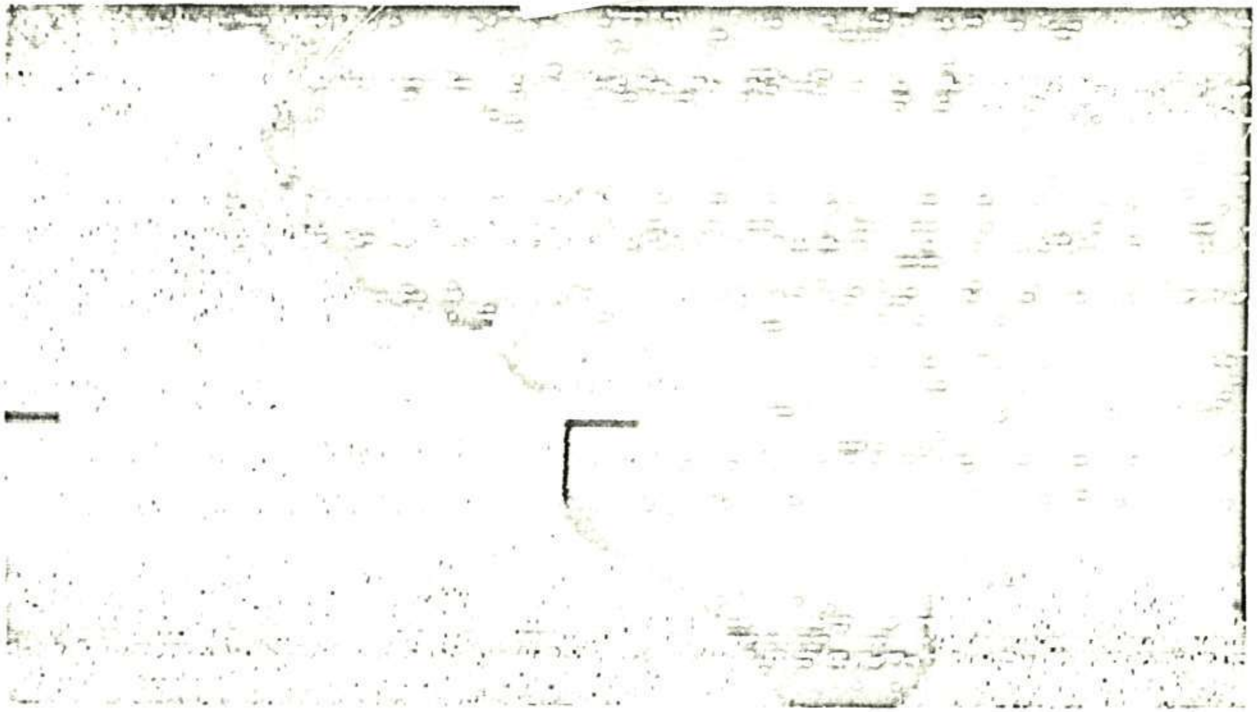

FIGURE 2a. Dust flow over the Mediterranean is recognized by the diffuse gray strip from the cirro-altocumulus and stretched from Lybia to Greece. TV image from ITOS-1 received in the Leningrad State University on the APT station July 16, 1970.

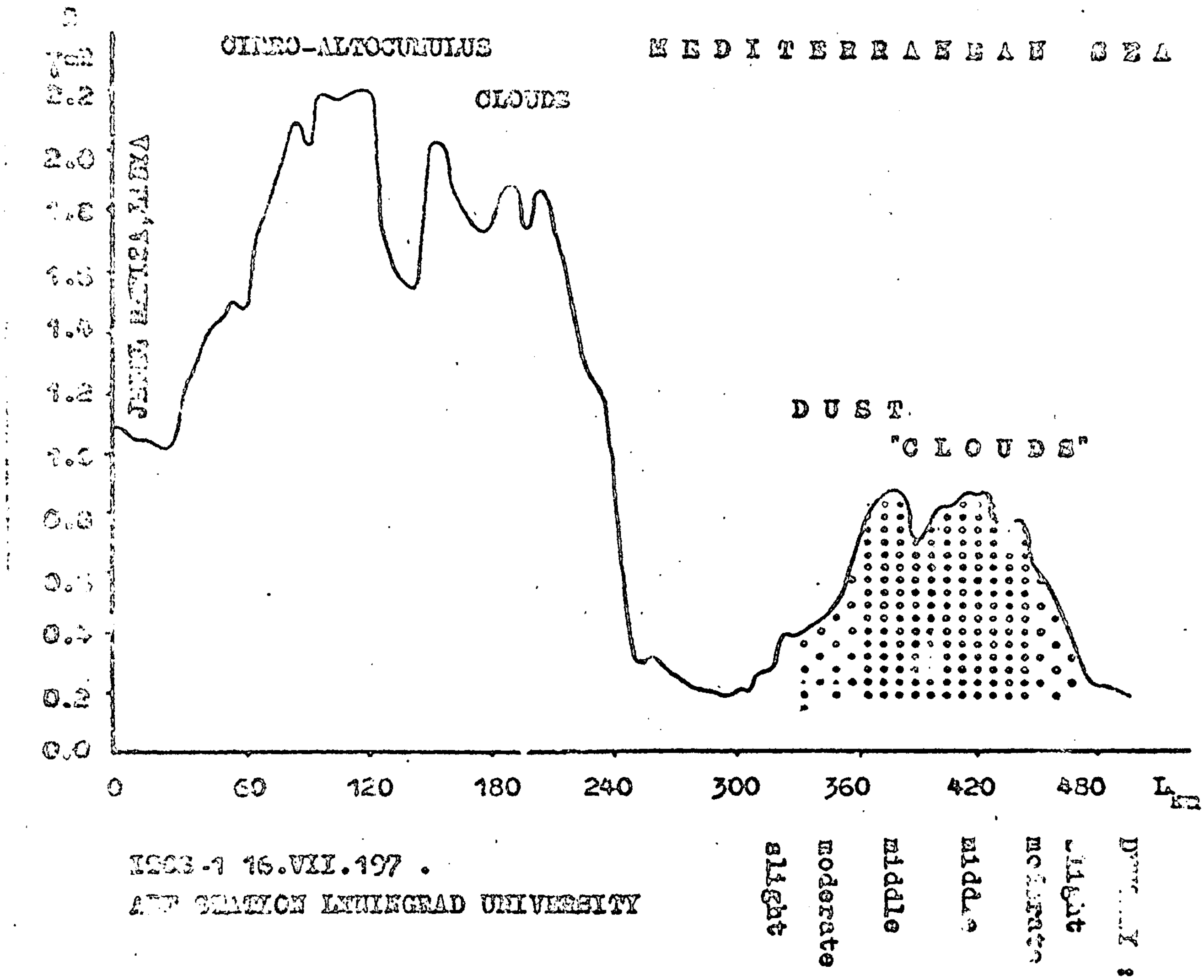

FIGURE 2b. Registrogram of the TV signal intensity across the cirro-altocumulus and dust clouds (with γ = 2) imageries.

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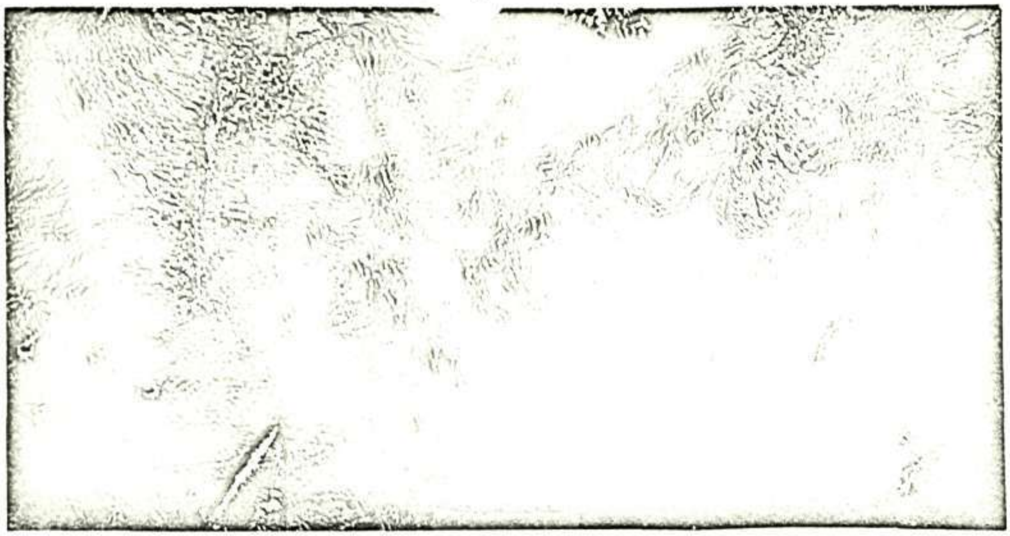

FIGURE 3a. Smoke plume of the Cooper Concentrating Plant, Douglas, Arizona; photo from Apollo 6.

LEGEND: (1) high density; (2) middle density; (3) moderate density; of smoke plume.

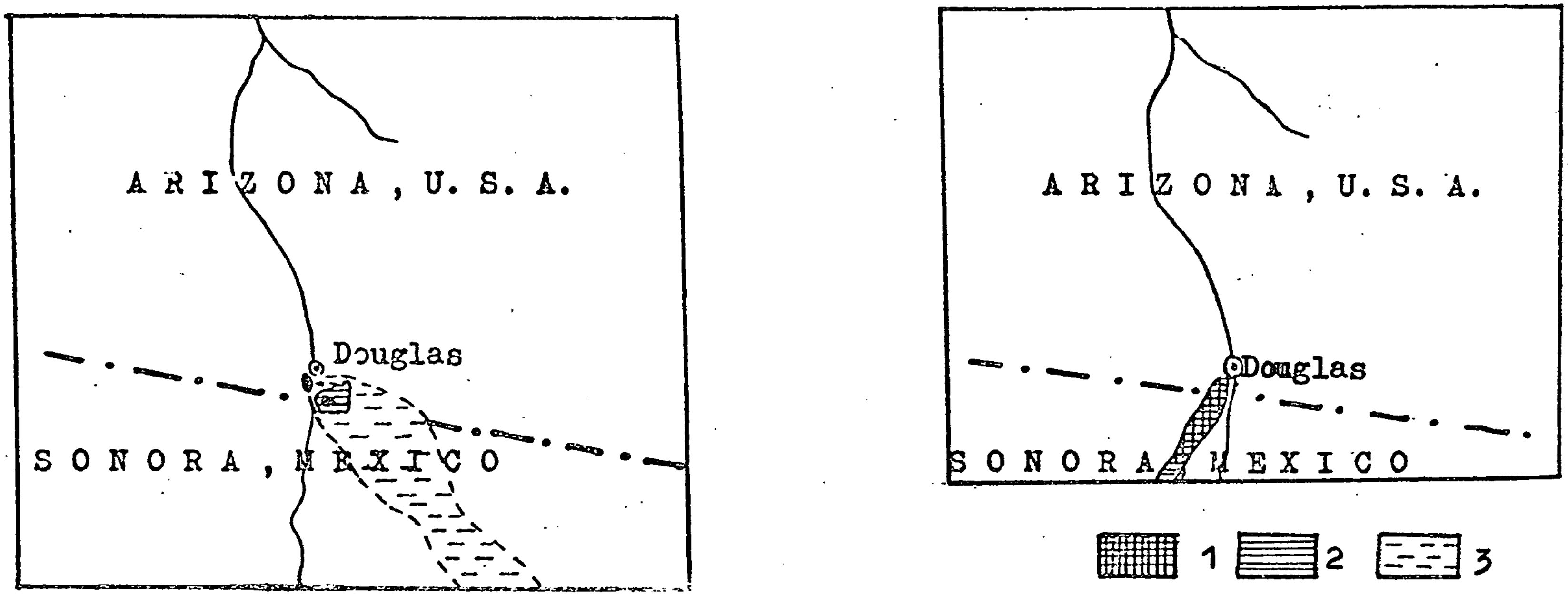

FIGURE 3b. Sizes and densities of the Cooper Plant smoke plumes as viewed from space photographs under different meteorological conditions: (1) diffuse pulsed smoke plume under unstable status of atmosphere and moderate wind velocity (from Gemini 4); and (2) cigar-shaped and raised dense smoke plume under stable status of atmosphere and middle wind velocity (from Apollo 6)

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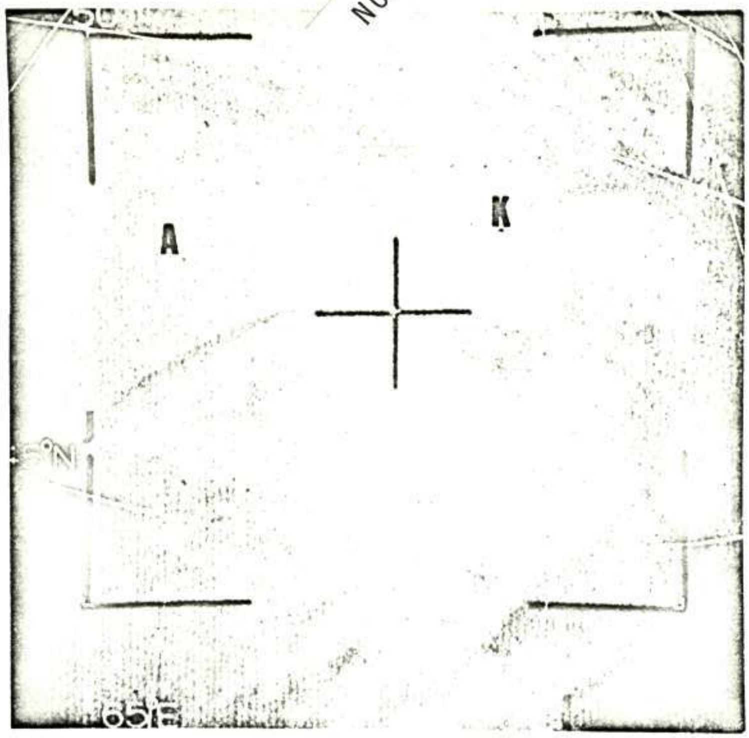

FIGURE 4. Jet stream (K) as interpreted from shadow track on cloud surface background (A). TV image from TIROS.